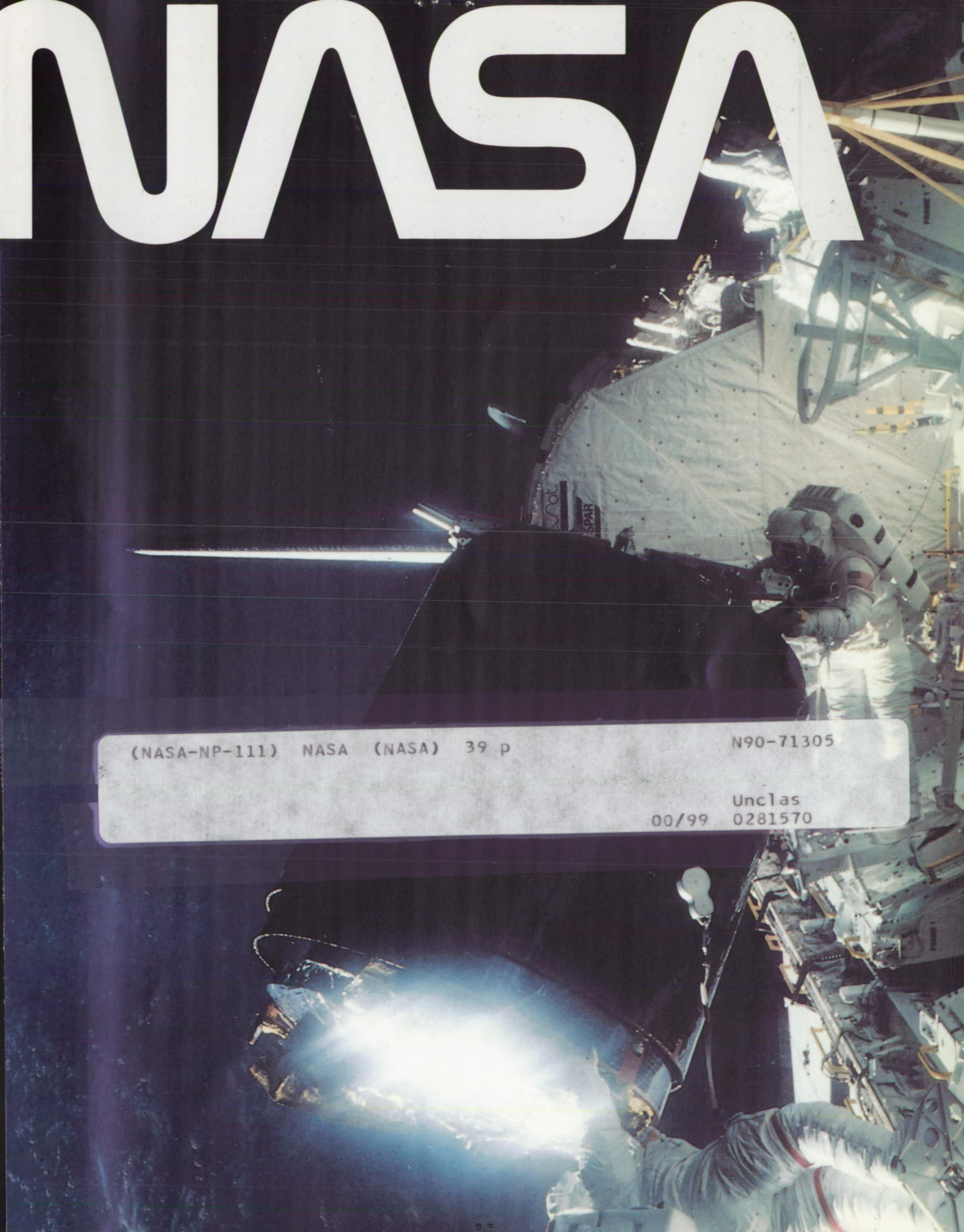
NASA



FOREWORD

Three Decades of Exploration

In 1958, the year NASA came into being, no one had ever seen a photograph of the whole Earth. Satellite weather maps were unknown. The far side of the Moon had never been photographed and some doctors and scientists still questioned whether human beings would be able to survive in the weightlessness of space.

In the past 30 years, we have answered some of our questions, and raised many more. We have made the first tentative forays into the vast emptiness beyond Earth, and found that humans can indeed survive "out there." We have stretched the limits of our technology, and raised our global consciousness.

At the forefront of this emergence of the human species from its home planet has been a unique federal agency, supported by the taxpayers of the United States. NASA stands at the edge of an American frontier, but also at the edge of human technology in the 20th century. The agency's scientists, engineers, astronauts, technicians and other civil servants are all united in the single mission of exploring unknown realms of air and space.

In the late 1980s, that mission has a new sophistication. The "easy" tasks—reaching the Moon, flying quickly past the planets of the solar system with robot probes—have been done. But we have yet to build a permanent base in orbit, or learn to live on the Moon, or send humans to Mars, or find out if life exists elsewhere in the universe.

Those challenges belong to NASA's future even more than to its past.

Administrator
National Aeronautics and
Space Administration

Earthrise as seen by the Apollo 11 astronauts, July 1969.

What is NASA?

The National Aeronautics and Space Administration is many things: the nation's civilian space agency; a diverse group of aeronautics research centers; employer of some 23,000 civil servants and 150,000 contract personnel; and operator of the Space Shuttle. As a federal agency, NASA belongs to the executive branch, like the Departments of Agriculture or Labor. Its concerns, however, are newer than those of most agencies. In fact, they were science fiction not long ago.

As a federal agency, NASA has clear tasks in its mission of conducting aerospace research. Nine major centers are spread throughout the continental United States, with headquarters in Washington, D.C. Dozens of smaller facilities, from tracking antennas to Shuttle landing strips to telescopes high on Hawaiian mountains, are located around the world. The agency administers and maintains these facilities, builds and operates launch pads, trains astronauts, designs aircraft and spacecraft, and sends satellites into Earth orbit and beyond.

NASA shares responsibility for aviation and space activities with other federal agencies, including the Departments of Commerce, Transportation and Defense. Much of the work on major projects such as the Space Shuttle and the Space Station is done in the private sector by aerospace companies under government contract.

As a research institution, NASA's scope is nothing less than the whole universe. While a scientist at one center studies the chemistry of a plant that may someday provide food for astronauts in orbit, an engineer at another center is figuring out how to build the supporting structure for an orbiting telescope that will study x-ray emissions from "black holes."

Some of the work is applied to specific problems—how to build a permanent orbiting Space Station for eight people, or how to design airplane propellers for maximum fuel efficiency. Just as often, it is research of the most basic kind. From its inception, NASA has been directed to pursue "the expansion of human knowledge of phenomena in the atmosphere and space." This program of basic research extends from the microscopic world of sub-atomic physics to the macroscopic view of galactic astronomy. By searching for connections and underlying principles, basic research is a wellspring of new ideas and new applications, and an essential ingredient for the advancement of knowledge.

There are direct economic benefits from NASA research—savings due to fuel-efficient aircraft design, for example, or the many thousands of "spinoff" technologies that have percolated through the commercial sector after being developed for aerospace applications. But always, the common thread of NASA's diverse activities is curiosity about the universe, our place and our future in it. It is a thread that extends from the agency's beginning in 1958 to an open and unbounded future.


UNITED
STATES
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NASA Then

On October 1, 1958, almost a year to the day after *Sputnik* 1 forever opened the door to a new frontier, a new federal agency called The National Aeronautics and Space Administration was created by the U.S. Congress. By combining a scattered handful of military space research programs with the existing National Advisory Committee for Aeronautics, Congress created a unique new civilian agency "to plan, direct and conduct aeronautical and space activities." NASA was born.

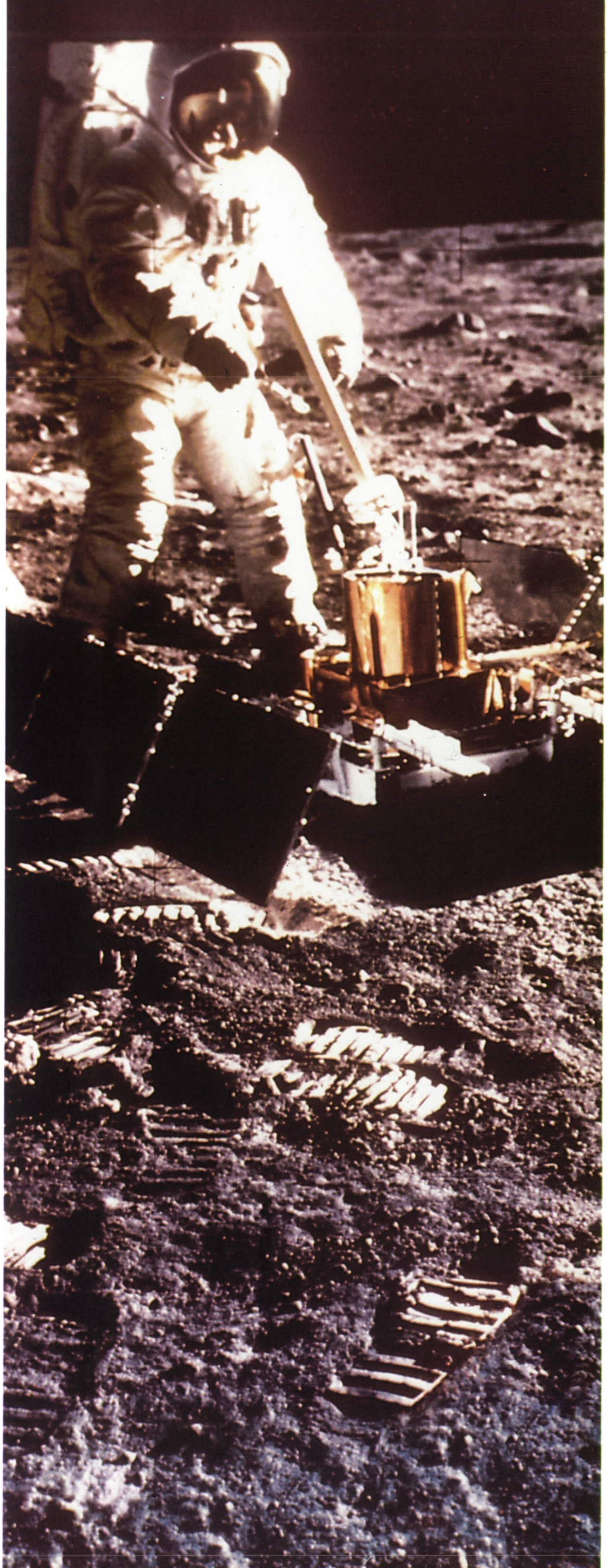
True to this simply stated mission, the agency was launching Pioneer, Explorer and other scientific satellites–projects previously initiated–within days of the Space Act's passage. Within a year, the first seven astronauts had been chosen. The six launches of the Mercury program followed from 1961 to 1963, proving that humans could reach orbit, survive there and return safely to Earth.

Within weeks of Alan Shepard's first Mercury flight in May 1961, a more ambitious goal had been set: landing a man on the Moon and returning him safely. The 10 Gemini flights that followed in 1965 and 1966 demonstrated key technologies such as orbital rendezvous, and showed that astronauts could live for weeks at a time in space, paving the way for the Apollo lunar landing program.

At the same time, NASA was actively exploring the Earth, Moon and other planets of the solar system with satellites. The TIROS satellites returned the first weather maps from orbit, and planetary probes—beginning with *Mariner* 2, which passed Venus at close range in 1962—were dispatched to all parts of the inner solar system.

Some intensive scientific studies also contributed to the lunar landing effort. The Ranger program conducted from 1961 to 1965 took the first close pictures of the Moon. Surveyor (1966-1968) followed with soft landings by robots on the lunar surface.

1961: The first Mercury astronauts ride into space on top of a Redstone rocket.



By 1968, the Apollo program had survived a launch pad fire that claimed the lives of three astronauts, and had progressed far enough to try for the Moon. In December of that year, the crew of *Apollo* 8 became the first humans to leave Earth's gravity and orbit another world.

Seven months later, on July 20, 1969, Neil Armstrong set foot on the Moon, fulfilling the dream of countless ages. *Apollo* 11 was the first of seven expeditions sent to the Moon between 1969 and 1972, six of which landed astronauts successfully on the surface. Twelve astronauts in all collected and returned hundreds of pounds of sample material from the lunar surface and set up scientific equipment that returned useful information for nearly a decade.

Even before the last lunar landing, NASA began to turn its attention to a task of equal, if not greater, difficulty, which still continues today—setting up permanent operations in Earth orbit. The Skylab program of 1973-74 proved the viability of a small, temporary "space station" where astronauts could stay for up to 90 days at a time, living, working and conducting experiments in virtually every field of science from Earth observation to galactic astronomy.

The Apollo-Soyuz Test Program of 1975, an orbital linkup of Soviet and American piloted spacecraft, was the last piloted U.S. spaceflight of the 1970s. During that same decade,

1969: Setting up scientific experiments on the Moon.

Pioneer probes crossed the asteroid belt for the first time and made the first close studies of Jupiter and Saturn. Mariner spacecraft visited Mercury, Venus and Mars. Then, in 1976, came the landings of *Viking* 1 and 2 on Mars and the first photographs taken on the surface of another planet.

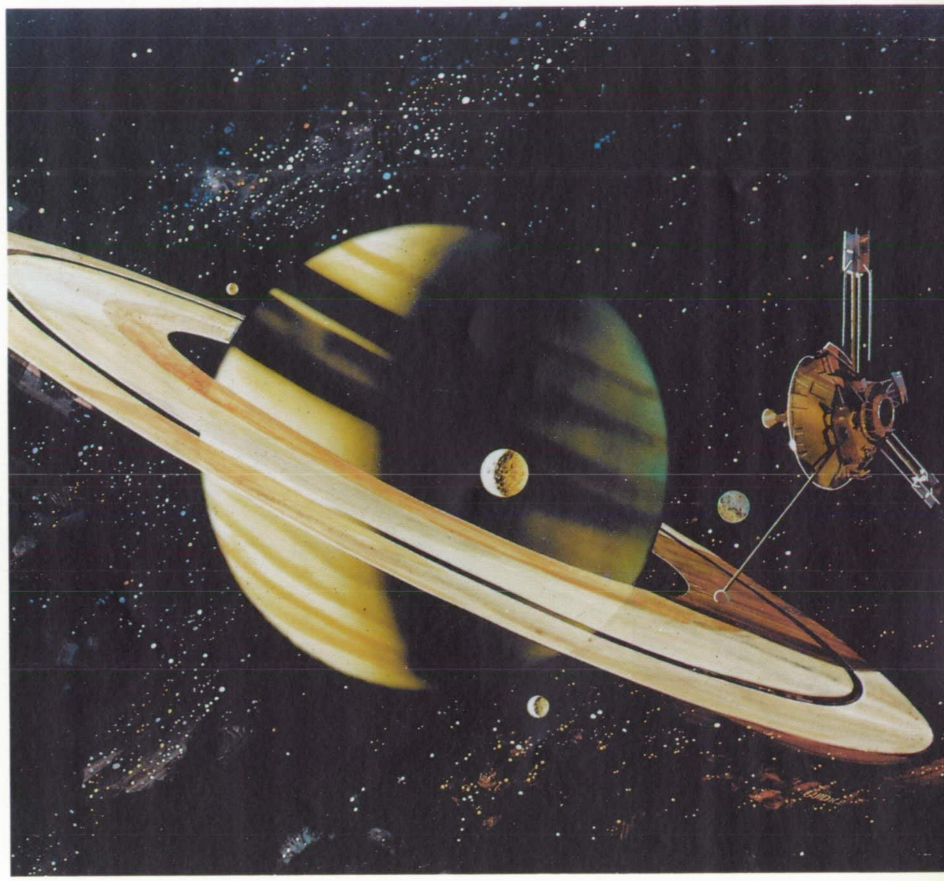
Two Voyager spacecraft followed in the late 1970s, for the most ambitious tour of all—close "fly-bys" of the outer solar system planets: Jupiter, Saturn and Uranus. *Voyager* 2 is still exploring, bound for a close look at Neptune in 1989.

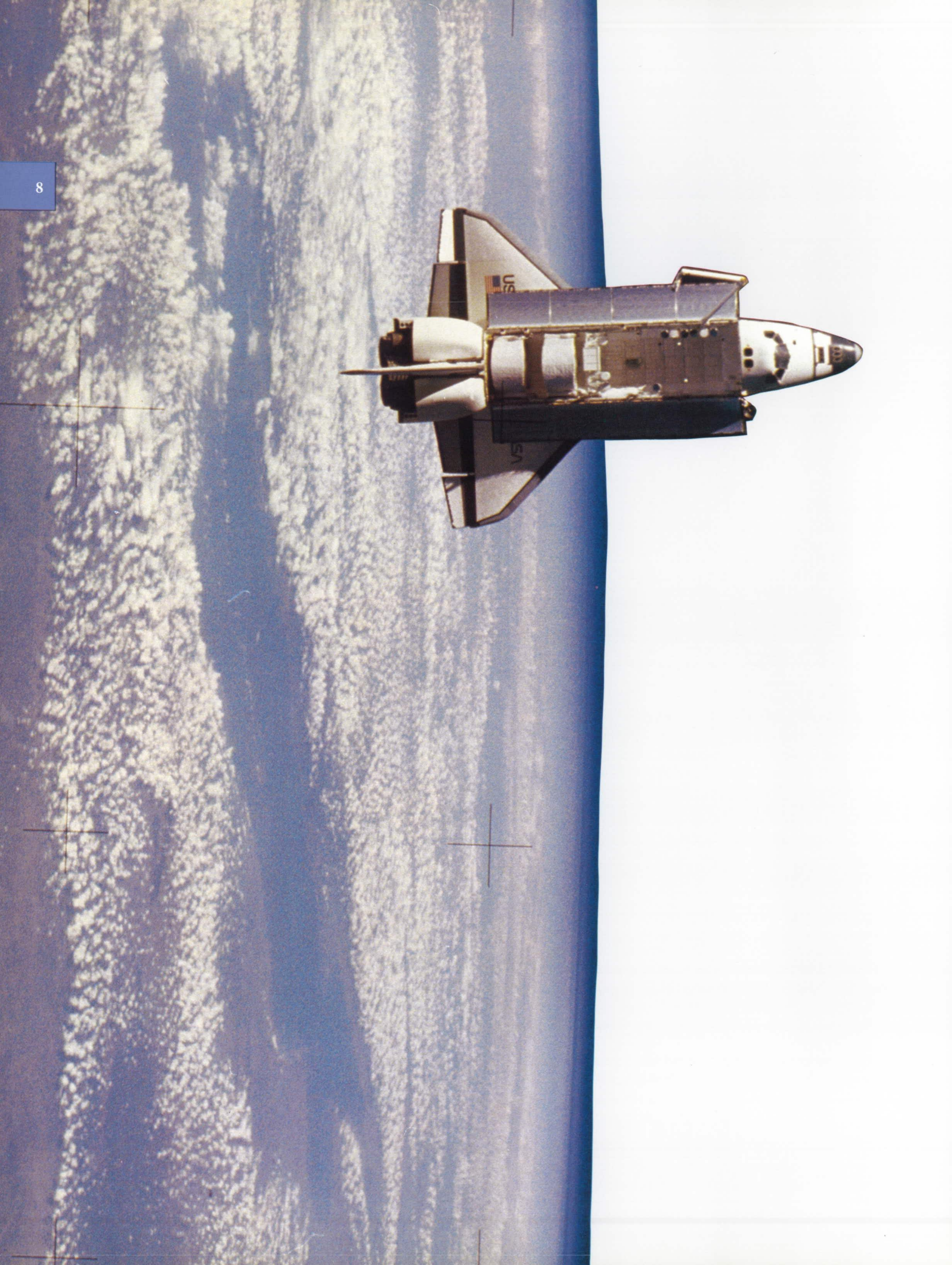
In 1981, a revolutionary new spacecraft made its first flight. Space Shuttle *Columbia* was launched upright into space, and two days later landed on a runway like an airplane. More importantly, it returned to space during that same year, to become the world's first reusable spacecraft.

The Space Shuttle flew 24 successful missions in its first five years, prior to the January 1986 launch accident that claimed the *Challenger* and its crew of seven. After a thorough re-evaluation and redesign period, the Shuttle returned to flight in 1988.

The Shuttle's regular access to Earth orbit will allow us to take the next step: building a permanent base in orbit. With the Space Station, a new era will open in the next century for a civilization that, at last, has a home off the Earth.

1979: Pioneer *11 explores Saturn.*





Doing the job: Where and Who

Headquarters

NASA Headquarters in Washington, D.C., coordinates all plans and activities, administers funds, and with the White House and the Congress, sets the policy goals for the space agency. Each major program has an office at Headquarters that directs specific projects carried out at the field centers.

Headquarters also has offices dedicated to general administration, including the Offices of the Comptroller; Policy and Planning; Procurement; Small and Disadvantaged Business Utilization; Management; Safety, Reliability, Maintainability and Quality Assurance; Equal Opportunity Programs; the General Counsel; the Chief Scientist and the Administrator.

Through its Office of External Relations, NASA Headquarters keeps close ties with other institutions, including other nations (International Relations Division); other federal agencies (Defense and Intergovernmental Relations Division); industry (Industry Relations Division) and the U.S. Congress (Congressional Relations).

The Office of External Relations also includes the Educational Affairs Division, which collaborates with the nation's educational community to help preserve U.S. leadership in aeronautics, space science and technology, and the NASA History Office, which documents the agency's past.

The Office of Communications extends information services to the public at large. The Public Services Division handles functions ranging from public inquiries about the space program to astronaut appearances, exhibits and guest operations for Space Shuttle launches and landings. The Media Services Division keeps the world press abreast of NASA activities by providing film, TV, radio, print and photographic materials for informing the general public. The Office of Communications is also responsible for internal communications, long-range television development and Freedom of Information Act inquiries.

Ames Research Center

Located just south of San Francisco at Moffett Field, California, Ames is active in aeronautical research, life sciences, space science and technology research. The world's largest wind tunnel is here, as is the world's most powerful supercomputer system—the Numerical Aerodynamic Simulation (NAS) facility, used for computational analyses ranging from aircraft design to astrophysics.

Ames also manages the Dryden Flight Research Facility, Edwards Air Force Base, California. Since the 1940s, this Mojave desert site has been a testing ground for high-performance aircraft, and is one of two prime landing sites for the Space Shuttle.

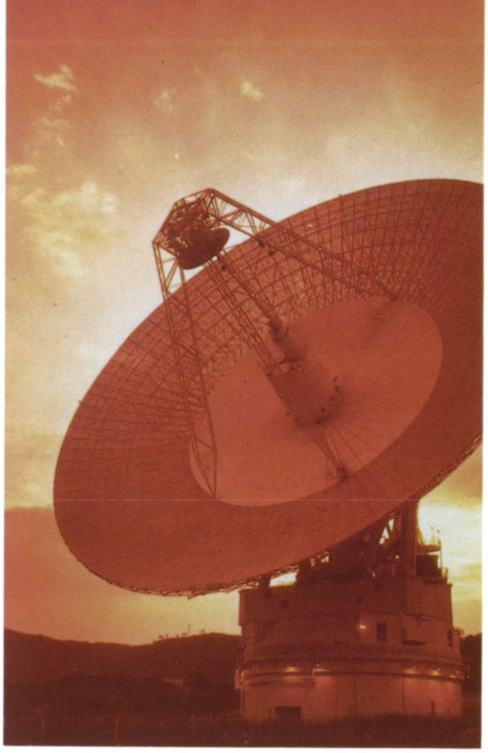
CRAY-2 supercomputers make the Numerical Aerodynamic Simulation Facility the most sophisticated computing system in the world.

Goddard Space Flight Center

Goddard was NASA's first major scientific laboratory devoted entirely to the exploration of space. The center, located in Greenbelt, Maryland, outside Washington, D.C., has six space and Earth science laboratories active in a wide range of disciplines, from infrared astronomy to climatology.

Goddard's responsibilities include the design and construction of new scientific and applications satellites, as well as tracking and communicating with existing satellites in orbit. Among the many programs managed by Goddard are the Tracking and Data Relay Satellite System and the Cosmic Background Explorer. Command and control of the Hubble Space Telescope, scheduled for launch in 1990, will be another of Goddard's responsibilities.

Goddard also directs operations at the Wallops Flight Facility on Wallops Island, Virginia, which each year launches some 50 scientific missions to suborbital altitudes on small sounding rockets.



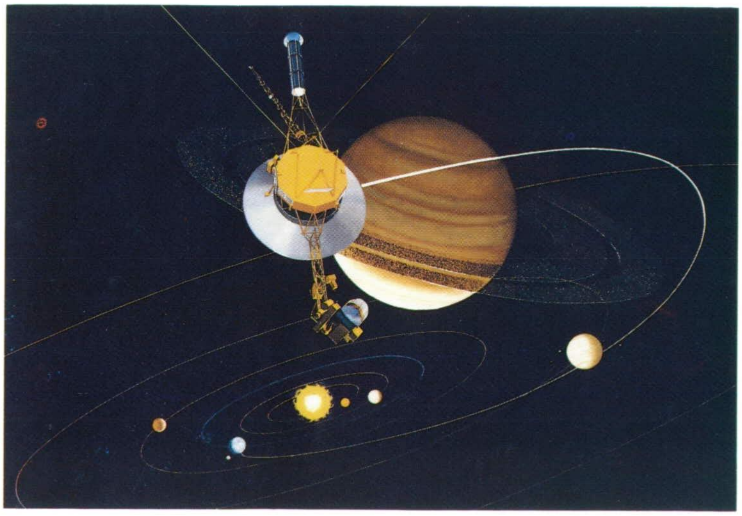
A Radio antenna in Madrid, Spain, part of the worldwide Deep Space Network.

Jet Propulsion Laboratory

Located in Pasadena, California, and operated under contract to NASA by the California Institute of Technology, the Jet Propulsion Laboratory (JPL) has as its primary focus the scientific study of the solar system, including exploration of the planets with automated probes.

Most of the lunar and planetary spacecraft of the 1960s and 1970s were developed at JPL, including the Voyagers that have explored the planets of the outer solar system. Among the lab's active flight programs are the *Galileo* mission to Jupiter, the *Magellan* mission to Venus and the Mars Observer.

JPL also is the control center for the worldwide Deep Space Network, which tracks all planetary spacecraft.



Voyager's "Grand Tour" of the outer Solar System includes encounters with Jupiter, Saturn, Uranus, and Neptune.

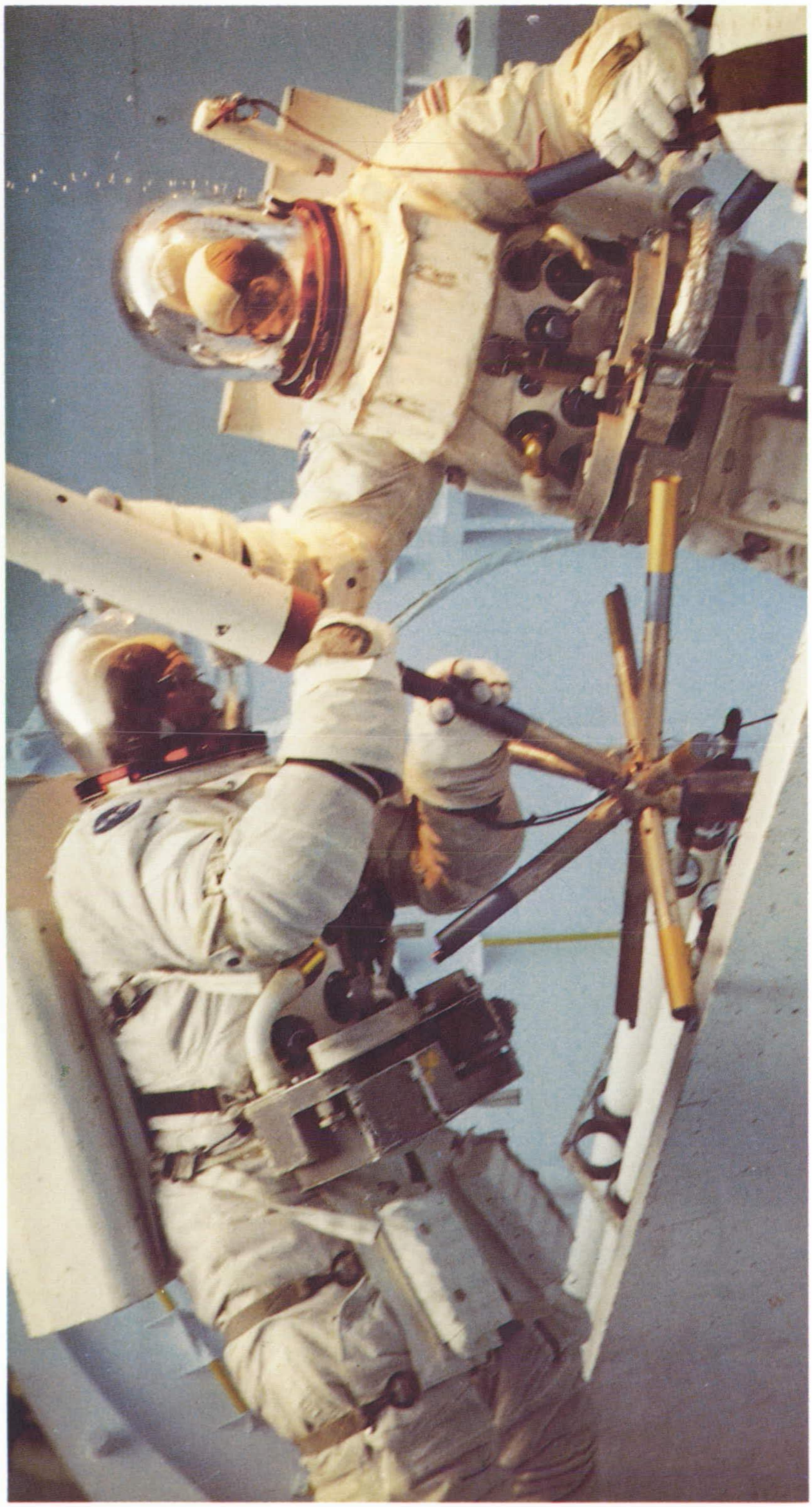
Lyndon B. Johnson Space Center

The Johnson Space Center, located between Houston and Galveston, Texas, is the lead center for NASA's piloted space flight program.

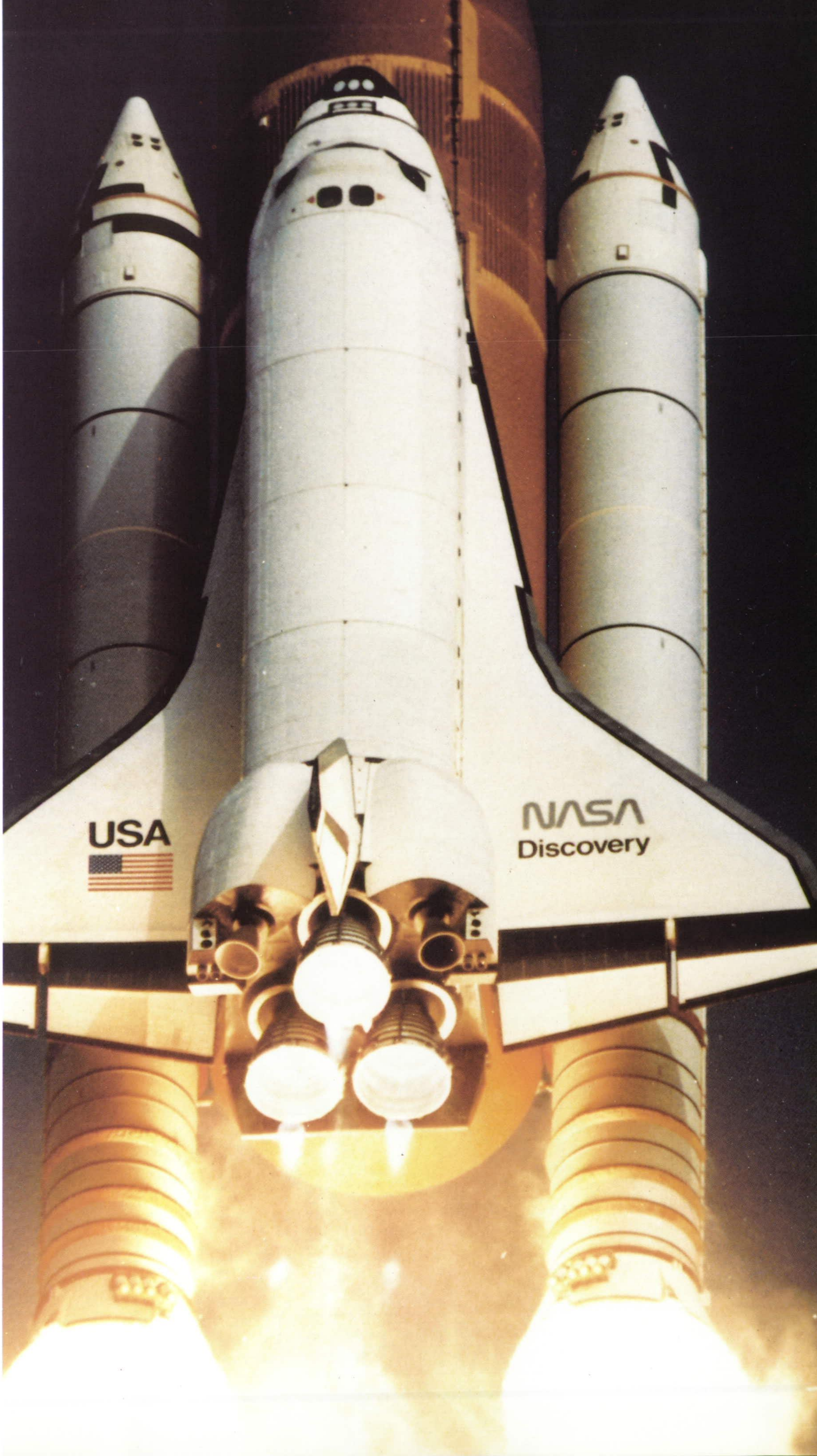
Johnson has been "Mission Control" for all piloted space flights since *Gemini* 4 in 1965 and now manages the Space Shuttle program. Today, the center has a major role in developing the Space Station of the 1990s.

Johnson's responsibilities include selecting and training astronauts; designing and testing vehicles and other systems for piloted space flight; and planning and carrying out space flight missions, including sponsoring onboard medical, engineering and scientific experiments.

In addition, Johnson directs operations at the White Sands Test Facility in New Mexico, which conducts Shuttle-related tests. The nearby White Sands Missile Range also serves as a backup landing site for the Space Shuttle, under the direction of the Kennedy Space Center.



Astronauts practice construction tasks of the future in a water-filled Neutral Buoyancy Simulator.



The Space Shuttle roars off the launch pad to begin mission 51-G in June 1985.

Kennedy Space Center

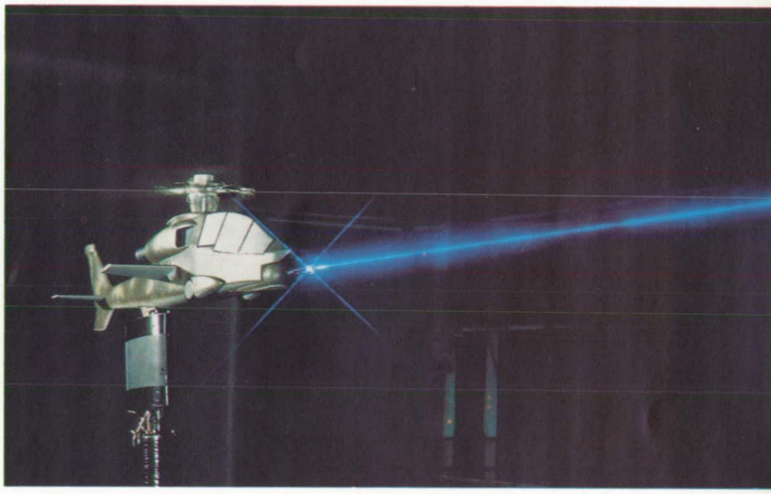
The John F. Kennedy Space Center, located near Cape Canaveral, Florida, is NASA's primary launch site.

The center handles the preparation, integration, checkout and launch of space vehicles and their payloads. All piloted space missions from the Mercury program on have been launched from here, including Gemini, Apollo, Skylab and Space Shuttle flights. Kennedy is the Shuttle's "home port," where orbiters are serviced and outfitted between missions, then assembled into a complete Shuttle "stack" before launch.

The center also manages the testing and launch of unpiloted space vehicles from an array of launch complexes, and conducts research programs in areas of life sciences related to human spaceflight.

Langley Research Center

The Langley Research Center in Hampton, Virginia, is the oldest of NASA's field centers, and focuses primarily on aeronautical research. Established in 1917 by the National Advisory Committee for Aeronautics, the center currently devotes two-thirds of its programs to aeronautics, and the rest to space. Langley researchers use more than 40 wind tunnels—including the National Transonic Facility used to simulate high-speed flight—to study improved aircraft and spacecraft safety, performance and efficiency. Programs now underway include developing technology for the joint NASA/Department of Defense National Aerospace Plane and for constructing large structures in space. Langley also supports agency-wide programs such as the Space Shuttle and Space Station by developing experiments and equipment for spaceflight.



Laser measuring devices aid in wind tunnel testing of advanced helicopter designs.

Lewis Research Center

The Lewis Research Center, outside Cleveland, Ohio, conducts a varied program of research in aeronautics and space technology.

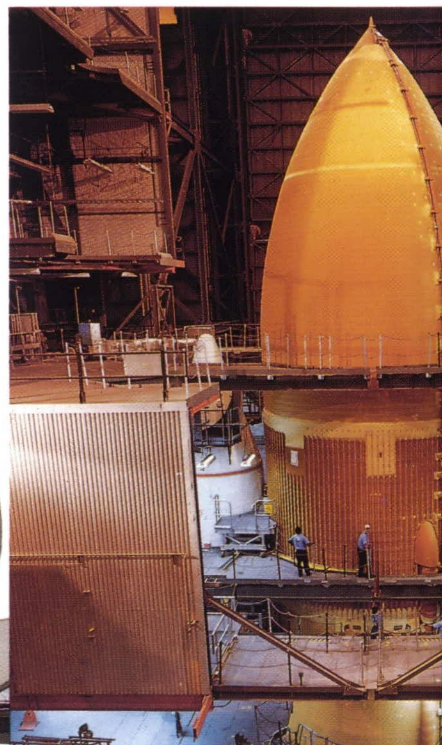
Aeronautics research at Lewis includes work on advanced materials and structures for aircraft. Space-related research focuses primarily on power and propulsion. Among the technologies investigated by Lewis engineers are chemical, nuclear and electric propulsion systems. Another significant area of research is in energy and power sources for spacecraft, including the Space Station, for which Lewis is developing the largest space power system ever designed.

Among the specialized facilities at Lewis is a Microgravity Materials Science Laboratory used to qualify experiments for spaceflight, and a zero-gravity drop tower that simulates weightlessness for short periods.

George C. Marshall Space Flight Center

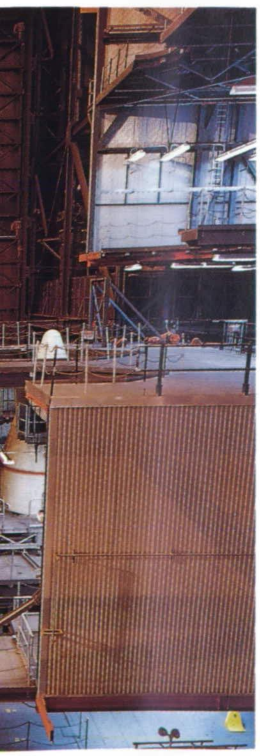
The Marshall Space Flight Center, Huntsville, Alabama, is responsible for developing spacecraft hardware and systems, and is perhaps best known for its role in building the Saturn rockets that sent astronauts to the Moon during the Apollo program. It is NASA's primary center for space propulsion systems.

Innovative propellers called "propfans" may increase the fuel efficiency of jet aircraft.



Marshall engineers and scientists participate in virtually all of the agency's major projects, including the Space Shuttle and Space Station. Marshall has lead responsibility for the Spacelab program, and for the Shuttle's solid rocket boosters and external fuel tank. In addition, Marshall is managing development of the Hubble Space Telescope.

Two other NASA sites are managed by Marshall: the Michoud Assembly Facility in New Orleans, where the Shuttle's external tanks are manufactured, and the Slidell Computer Complex in Slidell, Louisiana, which provides computer support to Michoud and to NASA's John C. Stennis Space Center.



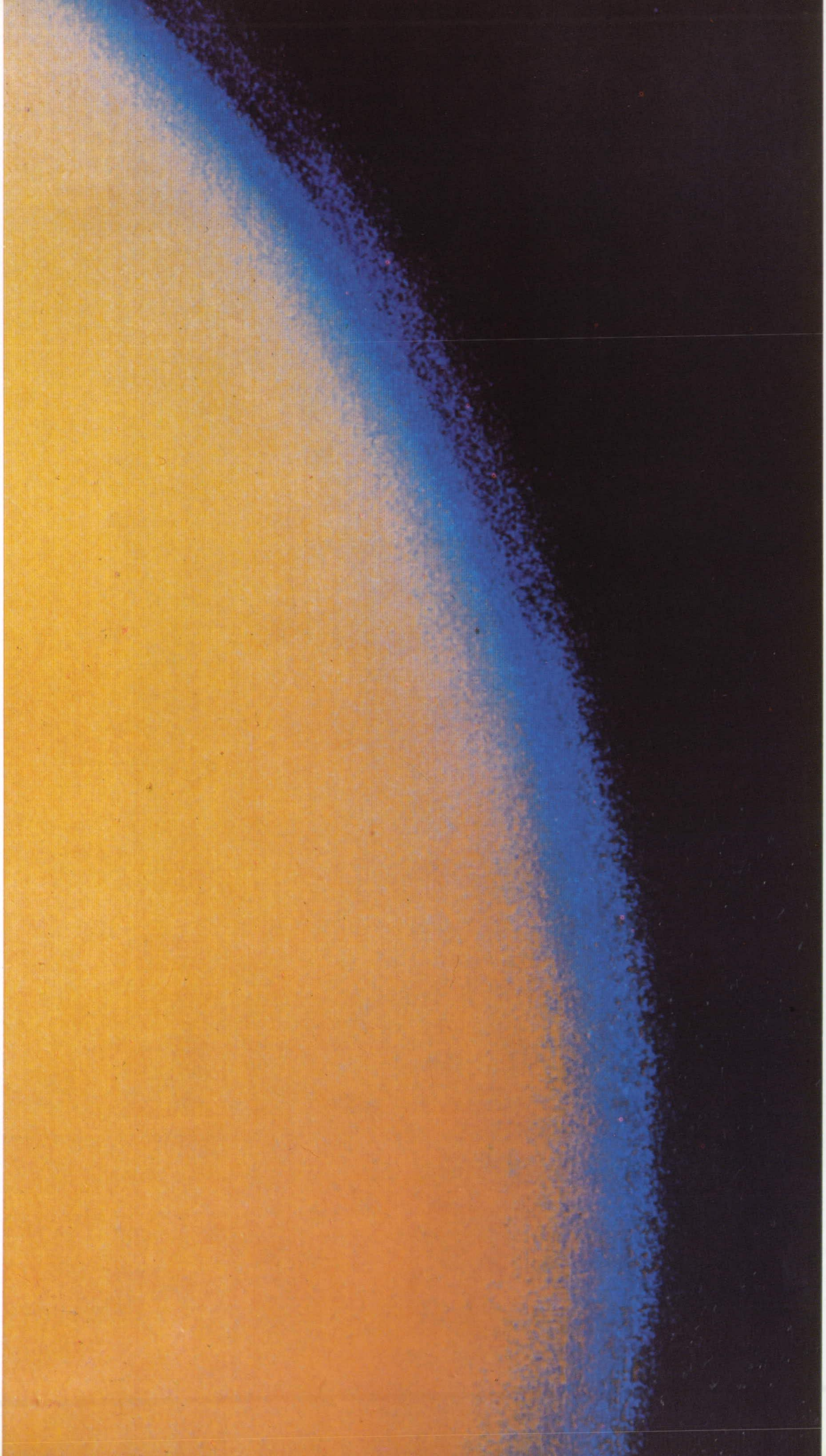
The Shuttle's giant external fuel tank is mated to its twin solid rocket boosters.

John C. Stennis Space Center

The Stennis Space Center located on Mississippi's Gulf Coast, is NASA's prime test facility for large liquid propellant rocket engines and propulsion systems. Currently, the main mission of the center is to support testing of the Space Shuttle main propulsion system, which takes place on a regular basis.

The Stennis Space Center is also responsible for a variety of research programs in the environmental sciences and the remote sensing of Earth resources, weather and oceans, and is the lead NASA center for commercialization of space remote sensing.

Shuttle main engines undergo testing at the Stennis Space Center.



The hazy atmosphere of Saturn's moon, Titan, is highlighted in this computer-enhanced image taken by Voyager *1.*

Programs

Science Programs

By exploring nature beyond Earth, NASA's scientific programs attempt to understand our own true place in the solar system and the universe as a whole. The Office of Space Science and Applications designs and carries out a wide range of research activities, extending from inside the Earth's core to the most distant observable galaxies.

Earth and Atmospheric Studies focus on the "home planet" as a dynamic system of land, ocean and atmosphere, which can be investigated on a large scale from space using remote sensing tools. Orbiting platforms such as the Upper Atmosphere Research Satellite, scheduled for launch from the Space Shuttle in the 1990s, will be used to study the global distribution of atmospheric gases. Also in the 1990s, an Ocean Topography Experiment satellite being developed jointly with France will give scientists their most accurate data yet on sea surface elevations.

NASA's Laser Geodynamics Satellites (LAGEOS) are among the spacecraft used for geological studies, particularly for measuring the movement of the Earth's crust with great precision. And Earth-observing instruments onboard the Space Shuttle and (eventually) the Space Station can be applied to a long list of scientific inquiries in meteorology, space physics, global ecology and the search for mineral resources.

A NASA-sponsored campaign of aircraft and ground experiments collected data in 1987 on the causes of atmospheric ozone depletion, a problem of growing concern to Earth scientists. This type of study fits into a larger interagency program to investigate the human causes and consequences of global change.

Space Life Sciences concern both the search for life beyond Earth and the study of how terrestrial life adapts to the "new" environment of space. An important part of the Life Science Division's work is to ensure the health and safety of astronauts in orbit.

The Laser Atmospheric Wind Sounder, planned for launch into polar orbit in the 1990s, will be used to improve weather forecasting.

NASA life scientists also address such questions as how life arose on Earth and whether it exists elsewhere. These studies range from assaying the organic material in cometary dust collected by high-flying airplanes to conducting a Search for Extraterrestrial Intelligence (SETI) project, which (in the 1990s) will begin the most comprehensive effort yet to listen for radio signals that might be generated by intelligent extraterrestrials.

The Galileo *spacecraft will be launched in a folded-up position from the Space Shuttle in Earth orbit.*

Probes, Planes, Balloons and Rockets

NASA scientific experiments ride on many different types of vehicles. Specially outfitted aircraft carry infrared telescopes above the absorbing water of the Earth's atmosphere, or allow life scientists and materials researchers to experience brief periods of weightlessness.

Instrumented balloons carry sensors into the upper atmosphere, while small sounding rockets give scientists a quick and easy way to send x-ray detectors above the atmosphere on short, suborbital flights to observe supernovas.

From Earth orbit, Explorers and other satellites can look downward or outward, and probes can be launched toward other planets. The Shuttle/Spacelab combination can be used for virtually any kind of science, and in the 1990s the Space Station and Great Observatories will usher in a new era of space science, conducted from permanent facilities in Earth orbit.

Microgravity Science explores the most basic physics of how solids, liquids and gases behave in the peculiar environment of space. Experiments placed on the Shuttle, Spacelab and other vehicles study, for example, how fluids mix or how crystals form when there is no appreciable force of gravity influencing them.

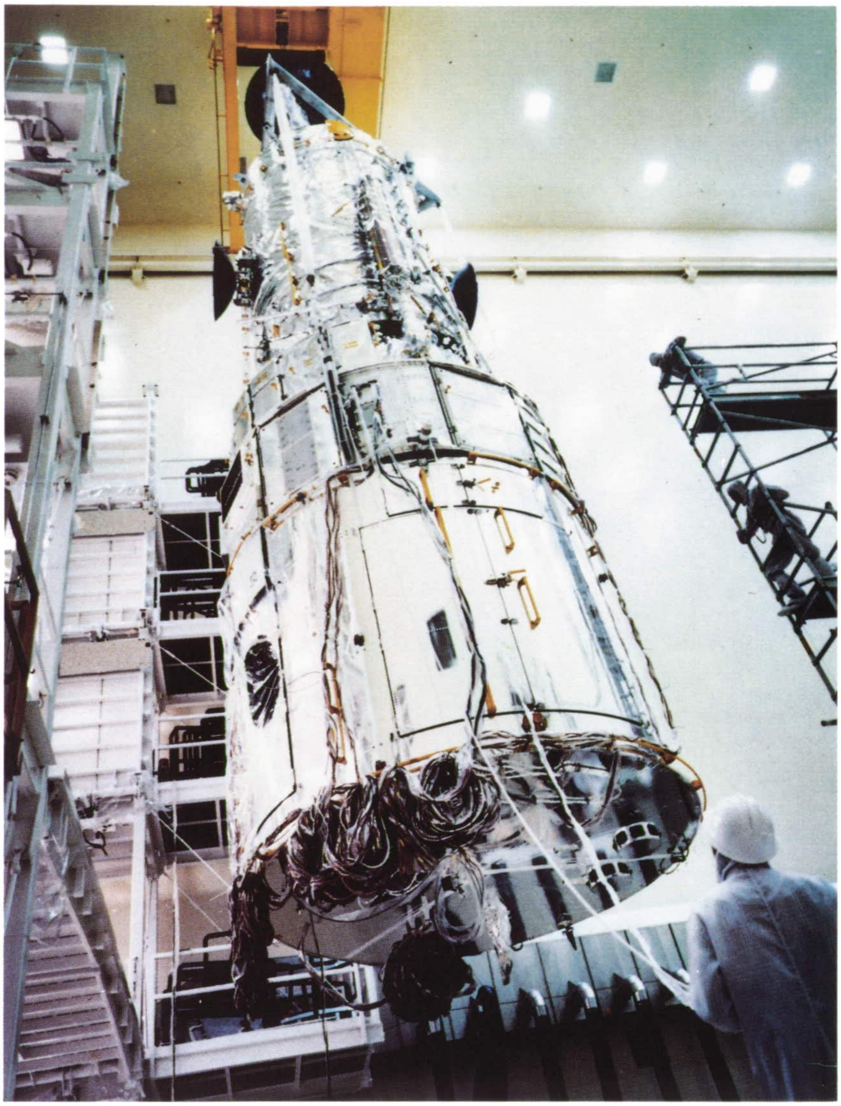
Solar System Exploration has been one of NASA's most active areas of research since the early 1960s. Having already launched spacecraft to all but one of the known planets (Pluto), the agency now is designing and preparing to launch a series of more advanced probes to the planets and the smaller bodies (comets and asteroids) of the solar system.

Besides continuing to receive data from such long-range explorers as the Pioneers and Voyagers, several new projects are planned: the Magellan radar mapping mission to Venus, which will produce the first high-resolution global map of that cloud-covered planet; the Galileo expedition to Jupiter, a two-year reconnaissance of the planet and its moons from Jupiter orbit; and the Mars Observer, which will map Martian surface chemistry and mineral distribution from Mars orbit.

All of these spacecraft, along with Ulysses, a European Space Agency/ NASA mission to explore the polar regions of the Sun, are scheduled to be launched between 1989 and 1992, and will be returning data well into the next decade. Possible future missions under study within the **Solar System Exploration Division** include a Comet Rendezvous and Asteroid Flyby and a mission called Cassini to orbit Saturn and its moon Titan.

NASA's Astrophysics and Space Physics divisions study the entire universe of stars and galaxies, including our own Sun. The **Space Physics** Division's Global Geospace Science program is part of an international effort to explore the solar radiation environment near Earth. By stationing satellites at various points in the inner solar system in the 1990s, scientists hope to gain a more complete picture of the invisible ocean of particles and radiation between the planets.

Galileo's *antennas and instrument "booms" will unfurl during the long voyage to Jupiter.*



Technicians check out the Hubble Space Telescope, planned for launch in 1990.

NASA's **Astrophysics** Division conducts Shuttle/Spacelab flights like the Astro-1 mission planned for 1990, as well as launching dedicated satellites like the High Energy Astronomy Observatories or the Gravity Probe B, which will test Einstein's theories of relativity from Earth orbit in 1994.

Beginning with the Hubble Space Telescope in 1990, NASA plans to launch a series of four "Great Observatories" into Earth orbit, where they will remain as permanent facilities. The most powerful astronomical tool ever developed, the Hubble Space Telescope will image astronomical objects with ten times the resolution, or clarity, of the best existing telescopes, and will see out to a far greater distance, over a much larger volume of space.

The next large facility planned after this visible light/ultraviolet instrument is the Gamma Ray Observatory, followed by the Advanced X-Ray Astrophysics Facility. A proposed Shuttle Infrared Telescope Facility would complete the series of Great Observatories, giving astronomers an unprecedented view of the universe across a large part of the electromagnetic spectrum.

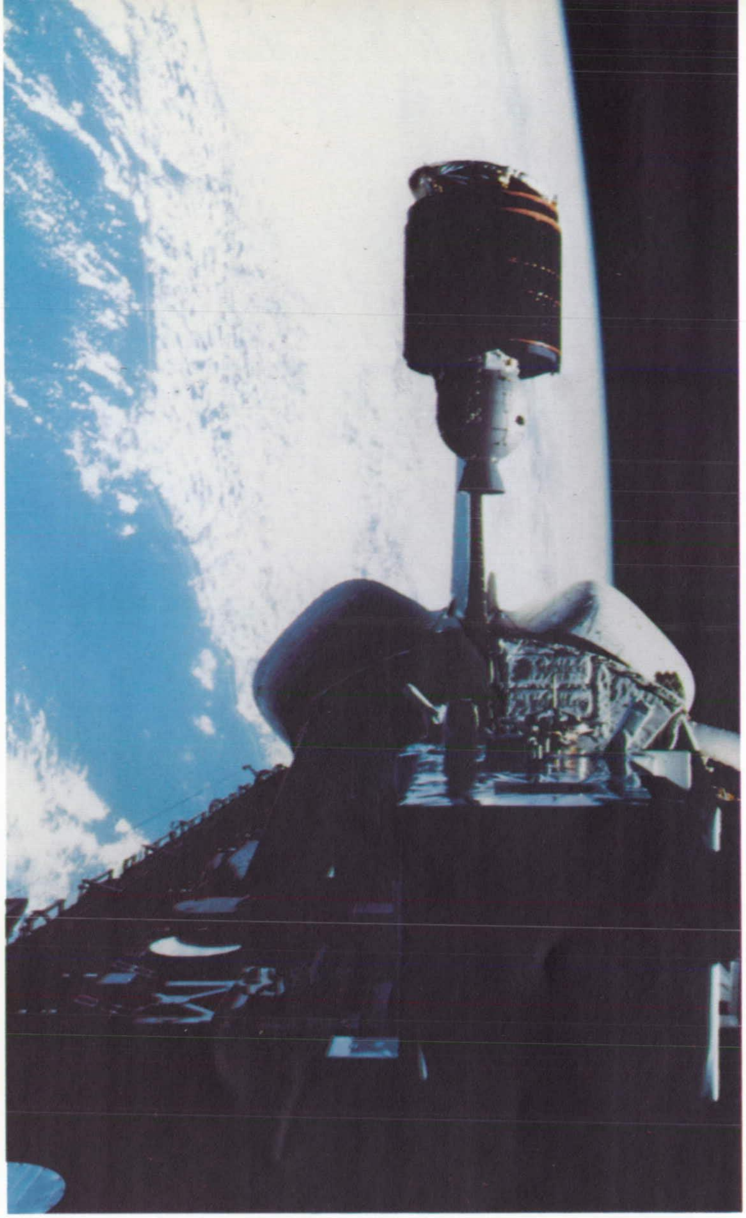
The Space Transportation System

The primary U.S. space launch vehicle—and currently the nation's only means of sending astronauts into orbit—is the Space Transportation System, otherwise known as the Space Shuttle.

NASA's Office of Space Flight manages this large and complex program, which involves every one of the agency's nine major centers. The lead center for the Shuttle, with responsibility for planning and conducting missions, is the Johnson Space Center near Houston; however, building, assembling, launching and servicing the Shuttle involves thousands of NASA employees and contractors nationwide.

The Space Shuttle includes not only the orbiter vehicle that travels into space, but also the giant External Tank that contains liquid hydrogen and oxygen propellants, and the twin Solid Rocket Boosters that provide most of the vehicle's thrust at liftoff.

The Space Transportation System includes even more: ground communication networks; orbital relay antennas; the Spacelab scientific laboratory; Mission Control operations; a training program for nearly 100 astronauts; Shuttle checkout, assembly and launch operations; landing operations; and the transport of orbiters from landing sites back to the launch pad, where they are prepared for another flight.



Among its other duties, the Space Shuttle serves as an orbiting platform for launching satellites.

Operating the Shuttle Fleet

Home base for the Shuttle fleet of three orbiters (*Columbia, Discovery* and *Atlantis*) is the Kennedy Space Center in Florida, where the space planes are housed and serviced in hangars called Orbiter Processing Facilities. Before a launch, the orbiter is "mated" to its fuel tank and boosters inside the cavernous Vehicle Assembly Building, then transported to one of two active launch pads.

Training for Space Flight

Although there is no way to fully simulate the space environment on Earth, NASA astronauts have a number of ways to prepare for Shuttle flights. Full-size mockups of the orbiter's cockpit-like flight deck are used by crews in training, while other simulators allow astronauts to practice with specific devices like the robot arm of the Shuttle's Remote Manipulator System.

Special facilities called Neutral Buoyancy Tanks—large water-filled pools—are used to simulate the easy motion of weightlessness. Astronauts practice their orbital tasks underwater, while wearing space suits with floats and weights attached to "neutralize" the effects of gravity.

NASA has no "anti-gravity" chamber on the ground for training astronauts, but it does operate specialized aircraft that can expose passengers and experiments to brief periods (up to half a minute) of apparent weightlessness as the aircraft levels off and begins to descend after a steep climb. These aircraft are used extensively in astronaut training.

Most Shuttle missions end with a touchdown on the dry lake bed at Edwards Air Force Base in California.

Satellites, experiments and other cargo to be included on the Shuttle come to the integration and launch facility at Kennedy from other NASA centers, government contractors and foreign countries. The majority of these payloads are either scientific or defense-related and are placed either in the orbiter's open cargo bay or inside the mid-deck below the Shuttle's flight deck.

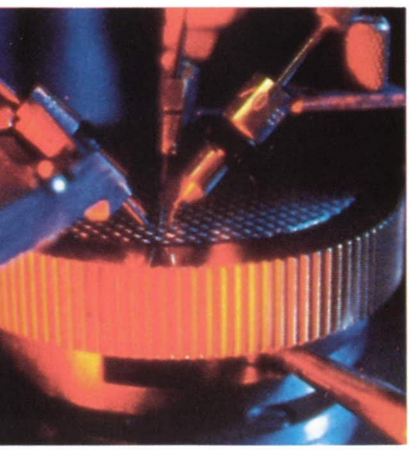
The Spacelab orbiting laboratory, which rests inside the Shuttle's cargo bay on selected missions, effectively adds more liveable room to the Shuttle, and is a key component of the Space Transportation System. The modular Spacelab can be assembled in several sizes and shapes. It allows scientists to work in a pressurized laboratory in the cargo bay, or it can expose pallet-like trays of automated experiments to open space.

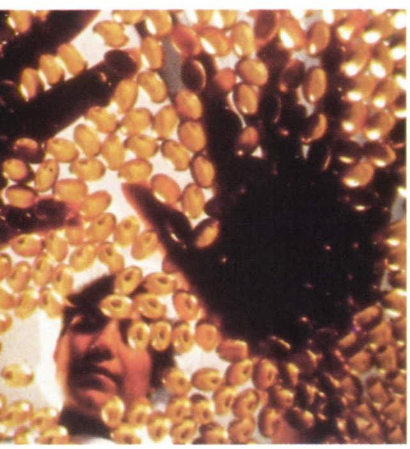
At the end of a Shuttle mission, the orbiter lands either at Edwards Air Force Base in California or the Kennedy Space Center in Florida, with the back-up landing site at the White Sands Missile Range in New Mexico. From the landing site the orbiter is ferried back to the Kennedy Space Center on the back of a NASA transport aircraft, where processing begins for its next flight into space.

Managing the Space Transportation System requires the coordination of this entire process. Solid Rocket Boosters and External Tanks manufactured by NASA contractors in Utah and Louisiana, respectively, must be on hand in Florida for final assembly with the orbiter. Upper stage rockets that boost payloads from low orbit to higher orbit must be attached to their satellites. Astronaut crews must familiarize themselves not only with Shuttle systems, but also with a particular mission's payloads before reporting to Kennedy for the launch.

Launch operations cover a wide range of activities, from assessing weather conditions on the day of launch to retrieving spent rocket booster cases, which parachute back to sea to be refurbished for another flight. Similarly, crews at the landing site inspect the vehicle after its return to Earth and prepare it for the return to Kennedy.

After a California landing, the Shuttle orbiter is ferried back to its Florida base on the back of a 747 carrier aircraft.





Commercial Programs

Increased commercial activity in space has become a national goal. While the first three decades of space travel were dominated by government activity, the long-term future may very well belong to the private sector.

With this in mind, NASA has an ongoing program to encourage commercial activity in space. NASA will no longer maintain its own fleet of expendable launch vehicles—conventional rockets—as a complement to the Shuttle. Instead, the agency now plans to contract for commercial launch services to carry into space payloads that do not require the unique capabilities of the Shuttle or tending by astronauts.

NASA is playing a key role in this "privatization" of the U.S. launch industry by providing commercial launch firms with access to government-owned launch pads and associated facilities and services.

The Office of Commercial Programs has several major initiatives underway to stimulate the private sector's involvement in space, both "up there" and "down here." NASA offers cooperative agreements, which provide industrial researchers access to NASA technical capabilities.

NASA commercial programs stimulate the growth of new products and technologies, both in space and on Earth.

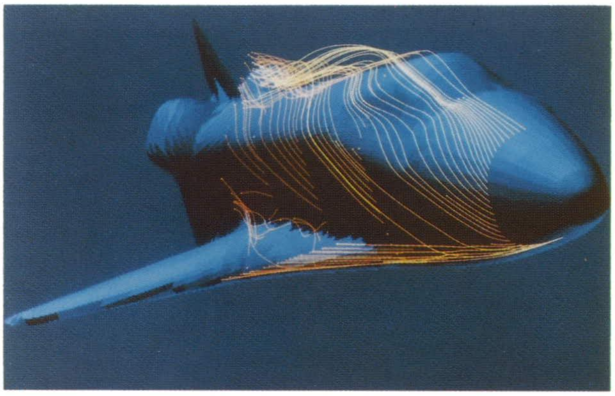
On Earth, the main focal points of NASA's commercial development program are the **Centers for the Commercial Development of Space**. These centers, sponsored and initially supported by NASA, are a unique research consortia of universities, industrial firms and the federal government. Their purpose is to investigate new products or technologies that might have commercial potential in space, from superconducting materials to robotics. Manufacturing of new high-value materials in the near-weightlessness onboard a Space Station could lead to the building of profitable orbiting factories in the next century.

Under its charter, NASA shares the benefits of space technology with U.S. private industry and public agencies through its **Technology Utilization** program. Thousands of "spinoff" products, from heart pacemakers to lightweight tennis rackets, have been derived from breakthroughs in aerospace technology. NASA transfers its technological know-how "from" space back to Earth through a nationwide chain of Industrial Applications Centers, and through the monthly publication, *NASA Tech Briefs*, which summarizes new technologies that may have secondary uses on Earth.

Among the many medical "spinoffs" from the space program is this cordless instrument, which drew on technology developed for the Apollo *program.*

Aeronautics

NASA was formed from the nucleus of the National Advisory Committee on Aeronautics (NACA), and has continued its predecessor's pioneering research in aviation technology.



Computer simulations of aerodynamic flow patterns lead to improved aircraft and spacecraft designs.

The agency's aeronautics program focuses on long-term emerging technologies aimed at maintaining U.S. leadership in civil and military aviation. It is virtually the only source of independent advanced aeronautics research in the country. The basic research in aerodynamics, aircraft materials and structures, propulsion, fuel efficiency and new aircraft design that goes on at NASA centers adds to the capabilities of the national aerospace industry, and helps to enhance U.S. competitiveness.

The tools available to aeronautics researchers at the Ames, Langley, Lewis and other NASA centers include several of the largest wind tunnels in the world. The recently inaugurated Numerical Aerodynamic Simulation (NAS) facility–the world's most powerful supercomputer–at the Ames Research Center adds a new capability for solving complex problems in fluid dynamics and airflow, prior to more expensive flight testing.

Among the major aeronautics research projects underway at NASA are:

Studies of advanced **propfan** designs, an effort to combine the best features of the jet turbofan engine and the airplane propeller. A Gulfstream II business jet, equipped with a wing-mounted propfan, is being used to test these revolutionary engine designs, with the eventual goal of increasing fuel efficiency.

The **High Alpha** flight research project, which is exploring new methods and technologies for giving supersonic aircraft unprecedented maneuverability and agility during very high-speed flight. An instrumented test vehicle made its first flight in 1987, while simulations and wind-tunnel tests continue.

The X-29, with its forward-swept wing, is the newest in NASA's "X" series of research aircraft.

Two new aircraft wing designs: the **X-29** "forward swept" wing, and the **Mission Adaptive Wing**, which is capable of changing its shape and aerodynamic characteristics depending on the speed of flight. The X-29 is flying test missions to evaluate new control systems and instrumentation as well as its revolutionary wing design. The Mission Adaptive Wing is being tested on an Advanced Fighter Technology Integration F-111 aircraft.

Rotorcraft studies, which include methods of reducing helicopter noise, and designs for advanced new vehicles. Basic studies of helicopter blade aerodynamics and blade shape contribute to programs such as the X-Wing Rotor Systems Research Aircraft, an instrumented test vehicle that combines the vertical-lift capability of a helicopter with the fixed-wing airplane's ability to fly at high speeds.

Participation (with the United Kingdom and the U.S. Department of Defense) in studies of an **Advanced Short Take-Off and Vertical Landing** Aircraft. NASA researchers are conducting an extensive flight test program to validate the control laws for these advanced vehicles.

Active research also continues in many areas of basic aeronautical research, from air flow over control surfaces to cockpit instrument design. One ongoing area of study is in reducing aircraft cabin noise due to propellers and propfans proposed for the aircraft of the 1990s.

Air traffic safety also is being studied at NASA: an advanced transport operating systems program underway at the Langley Research Center is working on new automation aids for passenger aircraft that would complement air traffic control on the ground to improve passenger safety.

The X-Wing Rotor Systems Research Aircraft combines elements of a helicopter with those of a fixed-wing aircraft.

Communications and Tracking

NASA's Office of Space Operations has responsibility for a global network of ground and space antennas, which handle communications and tracking for the Shuttle as well as other spacecraft. In a separate activity, the Office of Space Science and Applications is investigating requirements and possibilities for the next generation of communications satellites through its Advanced Communications Technology Satellite (ACTS) program.

NASA's Tracking and Data Relay Satellite System (TDRSS) will consist of three advanced satellites stationed in geosynchronous orbit 22,300 miles (35,680 kilometers) over the equator, and their associated ground stations. Once operational, the system will replace the old method of tracking spacecraft with a network of ground antennas located underneath the satellite's flight track. Instead, spacecraft signals and ground commands will travel "up" to the TDRSS satellites for relay. The three satellites together will survey the entire globe, providing near-constant communication with vehicles in orbit for the first time.

NASA also operates the Spaceflight Tracking and Data Network of ground antennas. The agency's Deep Space Network (DSN) of large (up to 70 meters in diameter) tracking antennas is used to keep in touch with our most distant explorers—the *Pioneer* and *Voyager* spacecraft now headed out of the solar system, as well as other planetary probes. The DSN has antenna facilities evenly spaced around the globe—in California, Australia and Spain—so as to be in constant "sight" of these deep space probes. The DSN antenna in Goldstone, California also will be used in the Search for Extraterrestrial Intelligence (SETI) radio survey scheduled to begin in the early 1990s.

A system of Tracking and Data Relay Satellites in orbit allows near-constant communication with spacecraft, including the Space Shuttle.

The very large array of radio telescopes near Socorro, New Mexico will be used to augment existing NASA tracking antennas for Voyager's encounter with Neptune in 1989.

Technology Research

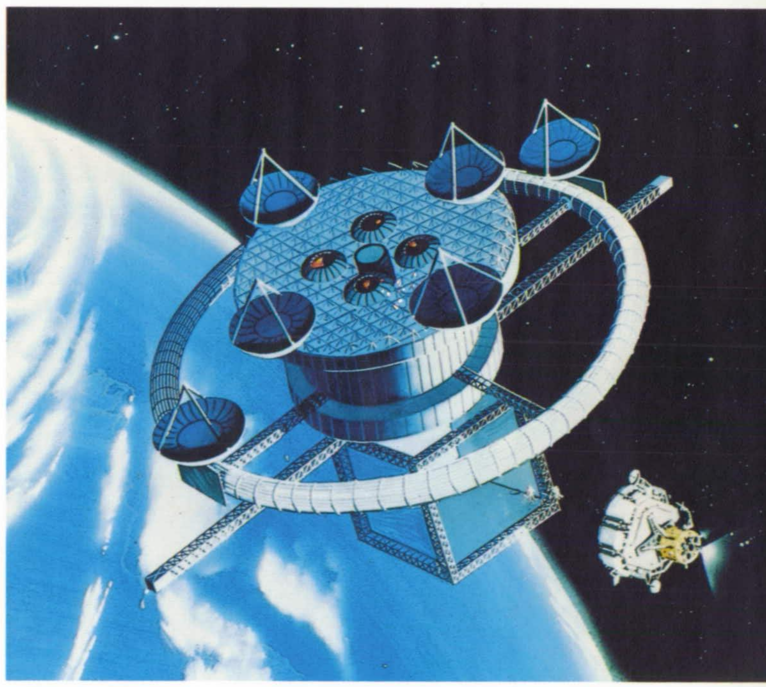
The Office of Aeronautics and Space Technology conducts a broad program of research and development to ensure that NASA has the basic technological tools to conduct its missions of exploration and discovery.

Power systems, engine propulsion, lightweight materials and aerodynamic structures are all ingredients necessary for spaceflight. Among the active areas in technology research are: development of new space suits for use outside the Space Station; construction methods and computerized stability controls for large structures in space; and lightweight tanks for cryogenic rocket fuels.

The **Civil Space Technology Initiative** (CSTI) is a program to explore new technologies for reaching Earth orbit cheaply and efficiently, and to conduct operations there. The major areas of research under CSTI include propulsion, aerobraking (a technique whereby spacecraft would use the Earth's atmosphere to slow their re-entry from space), high data rate communications, automation and robotics.

What CSTI does for Earth orbit, the **Pathfinder** program does for points beyond. By strengthening the base of space-related technologies today, Pathfinder will make possible such future missions as a return to the Moon or a human flight to Mars.

Among the prime areas of focus for Pathfinder are power generation in space and on other planets, automated rover missions to Mars (including sample returns), optical communications with deep space probes, rendezvous and docking in orbit, resource development on the Moon and Mars, new electrical propulsion techniques and such human-related technologies as a closed ecology life support system that would allow a long-term space crew to be self-sufficient in space.



An advanced space station like the one pictured here will require continuing research and development of new technology.


NASA
USA

A shuttle orbiter docks with Space Station *Freedom* in Earth orbit. The Station is scheduled for construction in the mid-1990s.

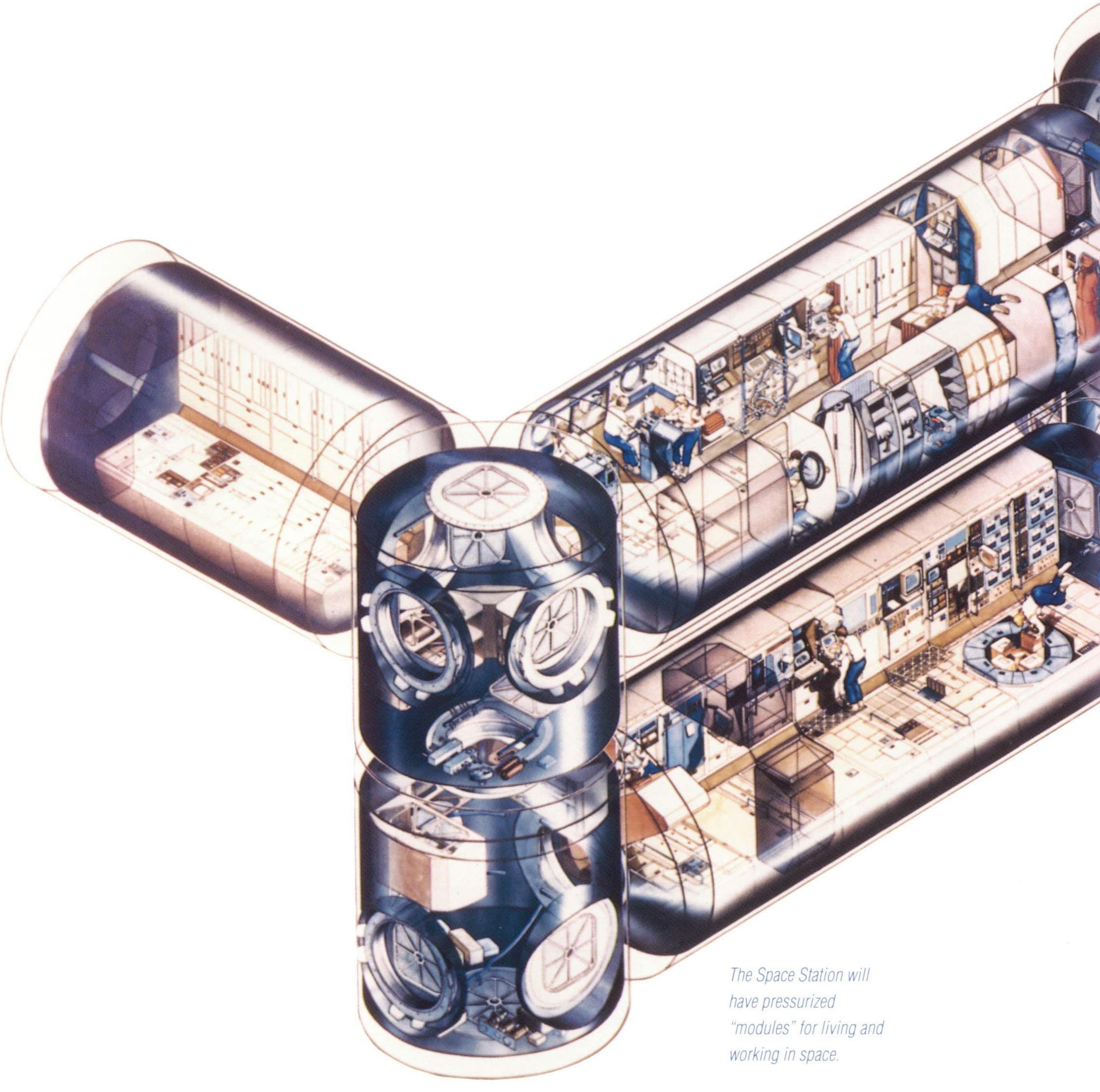
The Future

Space Station

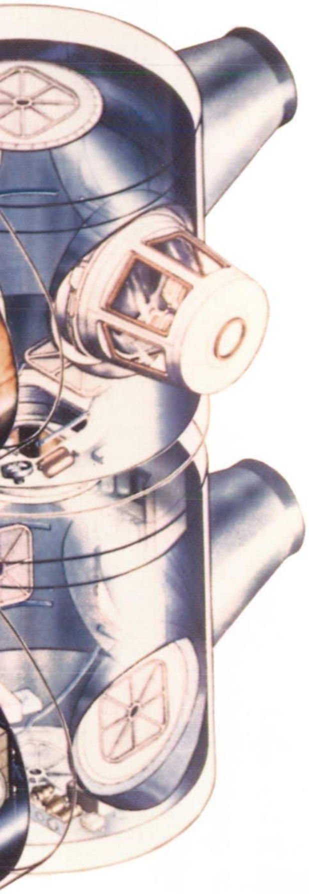
The NASA/international Space Station of the 1990s will be both a destination and a departure point. After more than thirty years of fitful visits into orbit, it will offer a permanent base where astronauts and visiting scientists can *stay* for long periods in space.

Now scheduled for construction beginning in the mid-1990s, the Space Station is a joint project of the United States, Canada, Japan and the nations of the European Space Agency. Orbiting approximately 250 miles (400 kilometers) above the Earth, the Station will be able to house eight people at a time. The first phase of the project will consist of four pressurized "modules"—living and working space for the crew and researchers. Huge panels of solar cells will provide electricity. A supporting mast, called a "transverse boom," will be the backbone of the facility, on which experiments, equipment and robotic arms for handling payloads can be attached. Free-flying, instrumented platforms in polar orbits will add still more capabilities.

The Space Station will be built, serviced and supplied by the Space Shuttle, which will also ferry passengers up to and down from the orbiting base. The range of activities planned for onboard the Station is as wide as the space program itself: Earth observation (including weather and resource monitoring), astronomy, life sciences and studies of new materials



The Space Station will have pressurized "modules" for living and working in space.



processing techniques are among the many activities that will take place inside and outside this space "research park."

In the next century, the Space Station will evolve into a full-scale operating base in orbit. Satellites in need of repair or upgrading will be brought to the Station's service hangar. Large construction projects in space—antennas, telescope arrays and more living and working facilities—will be managed from there, as will the steady traffic of satellites moving from low to high orbits.

Finally, the Station will be a foothold from which to move outward. At the Station, planetary probes will be attached to booster rockets and dispatched to all points of the solar system. Spacecraft carrying humans or robotic explorers to the Moon and Mars will use the Station as their shipyard and port: vehicles will be assembled and launched from there, and return there at mission's end.

The Space Station program was begun officially at NASA in 1984. Since then, an international team of government agencies and their independent contractors have been working on the massive task of designing the Station, leading to eventual construction, testing, launch, and assembly in orbit, now planned for the mid-1990s.

A mockup of Freedom's *galley is used to practice the housekeeping chores that will be needed in orbit.*

The National Aero-Space Plane

The National Aero-Space Plane will be able to go directly from a runway into orbit.

In a joint project with the Department of Defense, NASA is exploring the boundaries of atmospheric flight with the National Aero-Space Plane (NASP) program. If today's research leads to development of an operational vehicle, the aerospace plane could become a revolutionary new means of reaching orbit in the 1990s. The proposed craft could take off from a runway like an ordinary jet, climb into space or fly intercontinental "hops" at up to 25 times the speed of sound, then land again on a runway—with only a single reusable, built-in engine "stage" to power it.

Beginning in 1986, the NASP program began researching the required technologies for such an advanced vehicle. Current research is focused on understanding the aerodynamics and fluid dynamics of high-speed flight through different atmospheric regimes. Program managers are also studying advanced structures, high-temperature materials and new computer programs. Perhaps the biggest challenge is to develop the "scramjet" engines that would draw oxygen from the surrounding air during certain parts of the Aero-Space plane's climb to orbit, for use as a rocket fuel oxidizer.

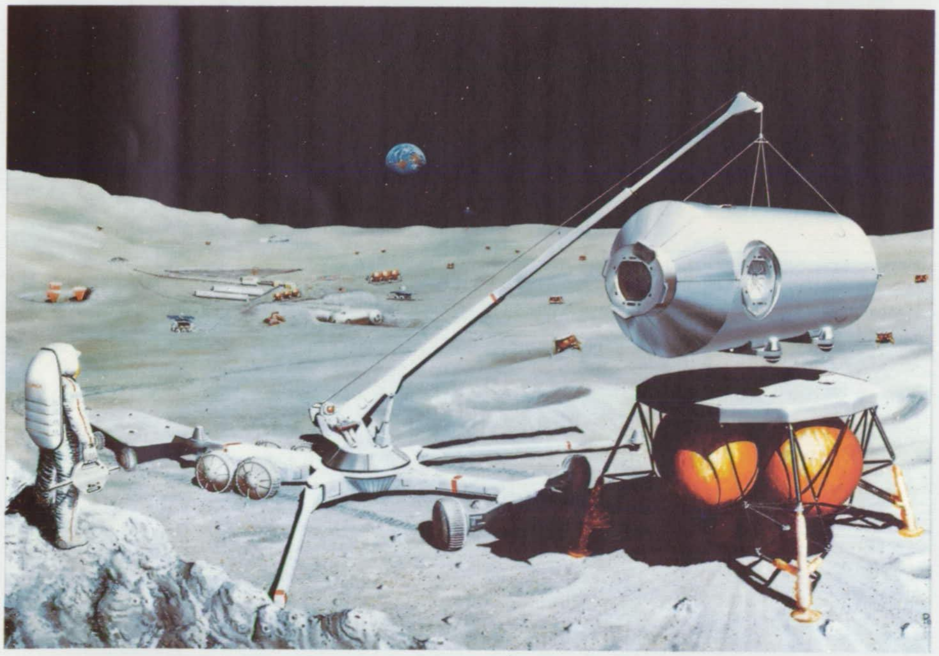
This research is in preparation for a planned flight demonstration of a prototype vehicle known as the X-30 in the early 1990s. If successful, this could lead to development of an operational Aero-Space plane in the next century.

Exploring the Moon and Mars

NASA's Office of Exploration was created in 1987 to coordinate the agency's long-term plans for expanding human presence off our home planet. This ambitious mission includes setting strategies and coordinating technical planning, as well as identifying the scientific advances and technologies that will be needed before such giant leaps can be made.

Establishing a permanent **Lunar Base** in the next century would require many other advances to be made first, from developing self-sufficient ecological systems to perfecting construction operations in Earth orbit and on the lunar surface. How best to transport people, equipment and living shelters to the Moon, and then how to sustain lunar scientific and logistic operations, are questions being studied in the Office of Exploration.

Similarly, a human **Mission to Mars** would require advances in long-term spacecraft reliability, life support systems, propulsion and many other areas. Precursor flights—robotic studies of the planet, perhaps including sample return missions—are likely to be undertaken before humans set out for Mars. At present, NASA has neither a lunar base program nor an astronaut mission to Mars underway. But laying the strategic and technological groundwork for these dramatic projects of the future is the ongoing task of the Office of Exploration.



A lunar base is among the ambitious projects under study in NASA's Office of Exploration.

Mission to Earth

The NASA project with perhaps the most immediate consequences for society would be a "Mission to Earth." In the late 20th century, scientists have become increasingly aware of large-scale environmental change due to human activity. If approved, a Mission to Earth would be NASA's contribution to a multi-agency, multi-national, multi-disciplinary scientific effort to understand the nature of this change. Currently, program planners in the Office of Space Science and Applications are studying the best ways to set up a global observational system in space. An array of orbiting sensors, working together, could give an unprecedented view of the planet as an integrated system of water, air, land and energy.

This "view from above"—a perspective that derives naturally from NASA's study of the other planets of the solar system—would have immeasurable value for any future program that addresses the critical subject of global change.

A F T E R W O R D

Toward Tomorrow

October 3, 1988, Space Shuttle *Discovery* completed a nearly flawless four-day mission, returning the nation to manned space flight. *Discovery's* success sets a far-reaching course in soace exploration that will include the *Magellan* flyby missin to Venus, the *Galileo* flyby mission to Jupiter and the Hubble Spave Telescope. As we approach the 21st century, the U.S. space program stands at a threshold, with the first voyages of discovery behind it and an entire frontier ahead. Humans have made their first tentative journeys to Earth orbit and the Moon, and robots have made the first reconnaissance of worlds that we have yet to explore fully.

The National Aeronautics and Space Administration, by the nature of its mission, looks toward that unexplored future. The agency's basic research in aeronautics, planetary exploration, astronomy and a dozen other disciplines pushes the limits of human science and technology.

In the late 20th century, that mission is vital to the nation's technological and economic competitiveness. In an even broader context, it is essential if we are to answer some of our oldest and most profound questions: who are we, and what is our place in the universe?

The Space Schuttle Discovery *and its five-man crew is launched from pad 39-B at 11:37a.m. as STS-26 embarks on a four-day, one hour mission.*

An astronaut evaluates the handrail system on the starboard longeron and aft bulkhead during a extravehicular activity.